

may best be exhibited so as to satisfy all the purposes for which they are intended. M. Felix Plateau, at a former meeting, proposed to substitute yellow for colourless glass in lighting rooms containing entomological collections. In the discussion which followed it was suggested that experiments should be made by submitting insects to the influence of glasses of various colours. M. Capronnier was entrusted with carrying out these experiments, and the paper referred to contains his report.

Everyone knows that among the Lepidoptera it is the green and carmine colours which are most rapidly destroyed by daylight. M. Capronnier wished to obtain insects of the year's hatching, but could only obtain sufficient quantities of *Euchelia Jacobae*, L. The inferior wings of this insect are of a deep carmine, uniform in tone, an important point in the experiments.

The principal colours of the solar spectrum are the yellow, the red, the blue. M. Capronnier rejected the red as giving a tint too dark, and added the mixed colours, violet and green. He had thus four tints chosen with the same degree of tone, and of a moderate shade—yellow, violet, green, and blue, besides a colourless glass. He made five small square boxes of .08 centimetres square and one centimetre in depth; the whole surface was covered with one of the above-mentioned glasses.

Each wing was fixed in the middle of the box and floated in a bath of very bright light, but protected from the rays of the sun. Each of the wings was partly covered by a band of black paper, and their position was so arranged as to leave exposed successively each of the parts during a period of fifteen, thirty, and ninety days. The following are the results:—

Colourless glass.—After fifteen days of exposure the carmine tint was visibly attacked. After thirty days the alteration was more sensible, and after ninety days the work of destruction had rapidly advanced, and the carmine had passed into a yellowish tint.

Blue.—With this tint the same alterations took place as in the case of colourless glass.

Green.—This colour preserved the carmine during the first fifteen days; a change was indicated on the thirtieth day, and on the ninetieth the alteration was marked.

Yellow.—During the ninety days the yellow alone left the carmine colour almost intact. M. Capronnier says *almost*, for a slight alteration in the tint could be noticed at the end of the ninety days. This last observation proves that there is no absolute preservative, and that collections must be kept in darkness, under penalty of seeing them seriously changed at the end of a given time.

Nevertheless, it is evident from the above that the yellow is the best preservative against alterations in the colours of insects. M. Capronnier consequently concludes that a yellowish colour should be preferred and combined in every arrangement of an entomological room. Moreover the cloths that cover the show-cases ought to be yellow rather than green, and what is important and indispensable, the window-blinds ought to be absolutely yellow.

RADIOMETERS¹

DURING the discussion which followed the reading of Prof. Reynolds's and Dr. Schuster's papers at the last meeting of the Royal Society I mentioned an experiment bearing on the observations of Dr. Schuster. I have since tried this in a form; and as the results are very decided and appear calculated to throw light on many disputed points in the theory of these obscure actions, I venture to bring a description of the experiment, and to show the apparatus at work, before the Society.

I made use of a radiometer described in a paper com-

¹ "On the Movement of the Glass Case of a Radiometer." By William Crookes, F.R.S., &c. Read at the Royal Society.

municated to the Society in January last. I quote the description from paragraph 184. "A large radiometer in a 4-inch bulb was made with ten arms, eight of them being of brass, and the other two being a long watch-spring magnet. The discs were of pith, blackened on one side. The power of the earth on the magnet is too great to allow the arms to be set in rotation unless a candle is brought near, but once started it will continue to revolve with the light some distance off."

This radiometer was floated in a vessel of water and four candles were placed round it, so as to set the arms in rotation. A mark was put on the glass envelope so as to enable a slight movement of rotation to be seen. The envelope turned very slowly a few degrees in one direction, then stopped and turned a few degrees the opposite way; finally it took up a uniform but excessively slow movement in the direction of the arms, but so slow that more than an hour would be occupied in one revolution.

A powerful magnet was now brought near the moving arms. They immediately stopped, and at the same time the glass envelope commenced to revolve in the opposite direction to that in which the arms had been revolving. The movement kept up as long as the candles were burning, and the speed was one revolution in two minutes.

The magnet was removed, the arms obeyed the force of radiation from the candles, and revolved rapidly, whilst the glass envelope quickly came to rest and then rotated very slowly the same way as the arms went.

The candles were blown out; and as soon as the whole instrument had come to rest, a bar-magnet was moved alternately from one side to the other of the radiometer, so as to cause the vanes to rotate as if they had been under the influence of a candle. The glass envelope moved with some rapidity (about one revolution in three minutes) in the direction the arms were moving. On reversing the direction of movement of the arms the glass envelope changed direction also.

These experiments show that the internal friction, either of the steel point on the glass socket, of the vanes against the residual air, or of both these causes combined, is considerable. Moving the vanes round by the exterior magnet carries the whole envelope round in opposition to the friction of the water against the glass.

As there is much discussion at present respecting the cause of these movements, and as some misunderstanding seems to prevail as to my own views on the theory of the repulsion resulting from radiation, I wish to take this opportunity of removing the impression that I hold opinions which are in antagonism to some strongly urged explanations of these actions. I have on five or six occasions specially stated that I wish to keep free from theories. During my four years' work on this subject I have accumulated a large fund of experimental observations, and these often enable me to see difficulties which could not be expected to occur to an investigator who has had but a limited experience with the working of one or two instruments.

COMPRESSED AIR LOCOMOTIVE USED IN THE ST. GOTTHARD TUNNEL WORKS¹

THE boring of a tunnel of any importance presents difficulties of various kinds, among which may be mentioned the clearing away of the rubbish arising from the excavation of the gallery, whenever that reaches any considerable length, and the work is carried on with activity. Such were the conditions under which the boring of the Mont Cenis tunnel was carried on, and M. Fabre, the able contractor, has met with similar difficulties in the boring of the St. Gotthard tunnel, now being carried out.

¹ From an article in *La Nature*, by M. C. M. Gariel.

The work was begun from two points, Airola and Göschenen, the two extremities of the future tunnel. The advance of the gallery, which is pushed on with activity, produces about 400 cubic metres of rubbish a day at each of the two faces of attack. To carry away this mass of rubbish, which is thrown regularly into trucks running on rails, it is impossible to employ locomotives, as the *cul de sac* nature of the galleries prevents

these machines would allow only pure air to escape; and then these motors would be more powerful than horses, and effect more rapidly the clearing away of the *débris*.

A first attempt was made in which two ordinary locomotives were employed, one at each side of the tunnel; the boilers, in which, of course, there was no water, were filled with condensed air under a pressure of four atmospheres.

This air played the part usually done by steam, passed into slide valves, entered the cylinders alternately on each face of the pistons, which it set in motion, and then escaped into the atmosphere.

It is easily seen that if compressed air were to be employed, it would be indispensable to have a very considerable quantity of it; the boiler of a locomotive, sufficient when it is worked by means of steam constantly produced under the action of heat, was too small to contain a quantity of air sufficient for use without being filled. This led to adding to each locomotive a special reservoir for compressed air; each locomotive was accompanied, as a kind of tender, by a long sheet-iron

cylinder, 8 metres long and $1\frac{1}{2}$ metres diameter, supported towards its extremities by two trucks, which, on starting, were filled with condensed air, and which communicated by a tube with the distributing apparatus of the cylinders. The locomotive then worked as before, except that compressed air came from the reservoirs instead of from the boiler. The two locomotives, the *Reuss* and the *Tessin*, worked economically for about two years, in spite of the

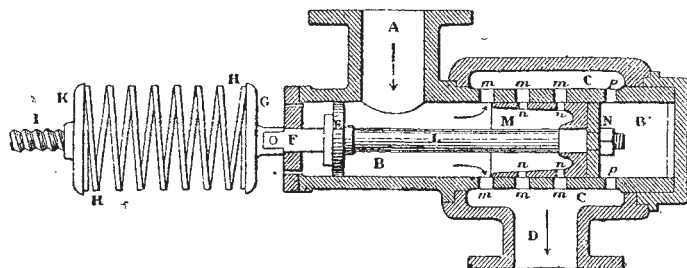


FIG. 1.

effectual ventilation. The high price of horses and the large number required prevent their use. The idea suggested itself of making use for St. Gothard of machines moved by compressed air, which would have many advantages. First, it is well known that compressed air is used to work the perforating machines used in boring the tunnel; then by the employment of compressed air locomotives ventilation of the galleries would be produced, as

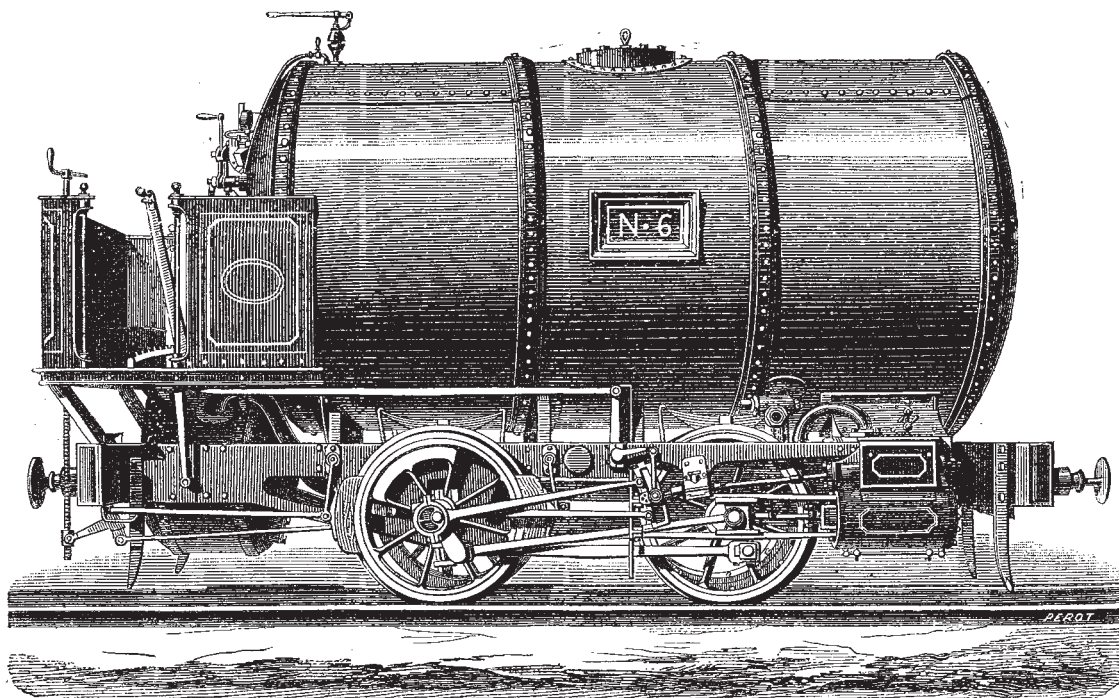


FIG. 2.—Compressed Air Locomotive used at the St. Gothard Tunnel Works.

awkwardness of the long cylinders that accompanied them. We can give some interesting figures resulting from the mean of a certain number of observations. At departure the pressure in the reservoir was about 7 kilogrammes per square centimetre; the locomotive having drawn a train of twelve loaded waggons along a course of about 600 metres, the pressure was found to fall to $4\frac{1}{2}$ kilogrammes; the train then returned empty to the point of departure, and the final pressure was found to be $2\frac{1}{2}$ kilogrammes.

In spite of the relatively advantageous results which were obtained, the employment of compressed air in a steam locomotive presented a certain number of drawbacks. It is expedient that the air should issue from the cylinder under the least possible pressure, in order that refrigeration may be reduced to a minimum; for it is known that the expansion of gas is accompanied by a loss of heat which increases with the pressure. This condition was satisfied by causing the air to act under restraint; that is, by allowing the compressed air coming

from the reservoir to enter during only a part of the course of the piston. But the admission of the air ought to vary if it is desired to obtain the same final effect, since the pressure in the reservoir diminishes continuously; and as the apparatus which regulates the admission was arranged to correspond only to determined fractions, but not to vary in a continuous manner, it followed that there was a greater expenditure of air than was necessary, and consequently a diminution in the length of the course over which the locomotive could run.

On the other hand it is necessary that the air should arrive in the distributing apparatus with the least possible pressure, for it is in this apparatus, in the slide-valve, that the greatest losses take place, and these losses increase in proportion to the pressure. No means could, however, be thought of for diminishing the pressure in the reservoirs, which would have reduced considerably the work which the machines were capable of doing, unless by augmenting considerably the volume of the reservoirs, the dimensions of which were already unusually large.

At this stage M. Ribourt, the engineer of the tunnel, devised an arrangement which allows the compressed gas to flow at a fixed pressure whatever may be the pressure in the reservoir. The gas in escaping from the reservoir enters a cylinder B (Fig. 1), over a certain extent of the walls of which are openings *mm*, that communicate with another cylinder C, which surrounds it to the same extent, and which is connected with the slide-valve by which the air is distributed, or, more generally, with the space in which this air is to be utilised. On one side moves a piston E, which shuts the cylinder and hinders the escape of the air. This piston carries externally a shaft F, which supports externally a spiral spring H, the force of which is regulated by means of a screw. Internally it is connected by another shaft I with a second piston N, which bears a cylinder M, movable in the interior of the principal pump, and forming thus a sort of internal sheath. This sheath presents openings *nn*, which may coincide exactly with those already referred to, and in that case the gas passes without difficulty from the reservoir at the point where it is to be employed. But if the sheath is displaced, the openings no longer correspond, there is resistance to the passage, and consequently diminution of the quantity of gas which flows out, and hence lowering of pressure in the exterior cylinder. By making the position of the sheath to vary continuously we may make the pressure of exit constant, notwithstanding the continuous variation at entry. But the apparatus is automatic. In fact the part of the cylinder B comprised between the bottom and the piston N communicates by openings *p* (which are never covered with the escape-tube of the gas), in such a manner that upon its posterior face the piston N receives the pressure of the gas at the moment when it flows, a pressure which it is sought to render constant. The piston E receives on its anterior face the action of the spring which can be regulated at pleasure. As to the other faces of the two pistons, they are subjected to equal actions proceeding from the pressure of the gas at its entry, actions which thus counteract each other; so that the forces which determine the position of the movable system are on the one hand the tension of the spring, a constant and determined force, and on the other hand, the pressure of the flowing gas; and thus equilibrium cannot occur unless the two forces are equal. If the gas should flow in too great quantity, the pressure increases on the posterior face of the piston N, the spring is overcome, and the movable system advances a little towards the left; but then the orifices are partly covered and the flow diminishes. If the pressure then becomes too weak at the exit, the spring in its turn prevails, pushes the sheath towards the right, uncovers the orifices, and consequently a greater quantity of air may enter.

The machines which are now used at the St. Gothard tunnel, genuine compressed air locomotives, are furnished with M. Ribourt's apparatus. They consist of the following parts:—A sheet-iron reservoir to contain the compressed air is mounted on a framework quite like that of steam locomotives, and carrying glasses, cylinders, distributing apparatus, &c. The tube for receiving the air possesses, within reach of the driver, the automatic valve of M. Ribourt. The screw being easily regulated, the air can with certainty be made to issue from the apparatus at a determined pressure. This air then passes into a small reservoir (about one-third metre cube) intended to deaden the shocks, which are always produced when the machine is set agoing or stopped. Lastly, this small reservoir communicates with the cylinders, and the air which reaches them acts in the same manner as steam in ordinary locomotives.

The pressure in the principal reservoir at the point of exit depends on the power of the compressing apparatus; at St. Gothard it may attain 14 kilogrammes per square centimetre, but is ordinarily about 7·35 kilogrammes. The pressure in the small reservoir is arbitrary, depending on the regulation of the screw; at St. Gothard it has a mean of 4·20 kilogrammes. The entire machine weighs about 7 tons.

PHYSICAL SCIENCE IN SCHOOLS

THE passages from Mr. Wilson's essay of 1867 and his letter of 1876 appeared to me in contradiction on the value of science in developing the power of reasoning and of language, since in his letter Mr. Wilson says that science should not be taught to boys till they have attained a certain power of reasoning and language as shown by their attainments in geometry and Latin; and in his Essay he speaks of science as supplying the want of clearness and certitude *better* than arithmetic or geometry, and again, as of all processes of reasoning the exhaustive illustration; and I wished to know whether Mr. Wilson had altered his opinion in the last ten years on this point.

The question at issue is as stated: "Given that boys are going to remain under a system of liberal education till eighteen or nineteen, at what stages is it shown by experience that it is wise to introduce the different sciences?" Certainly my experience has not been so extensive as Mr. Wilson's, but I possess the qualification he demands for forming an opinion, that while (during eight years) I have taught science I have also at various times been occupied with mathematics and with language.

The extent to which science should be introduced into the curriculum of a particular school, and the order in which the various subjects should be taken up, cannot, I think, be practically determined without taking into account various points of mere expediency. If, for example, expense were no consideration, I should prefer certain branches of physics, for example, magnetism and electricity, as the subjects for the *first practical* work to be undertaken rather than chemistry. But practically there is this difference, that a class of twenty or thirty boys in practical chemistry can be handled by one master with fair success; whereas the attempt to carry a *class* through any such course of physics as that sketched in Weinhold (translated by Foster) could, I think, only end in failure. Two or three boys to whom one master could give his whole attention might use the book with advantage, but a *class* could not be so handled, except at the additional cost of two or three assistants and considerable time for preparation.

Without, then, asserting that this is the plan theoretically best, we have been led by circumstances at Giggleswick into the following course:—

The school is divided into the upper school, and the lower (or preparatory) school; the upper school consists